

Exhibit 26 to Amended Complaint

Intellectual Ventures I LLC and Intellectual Ventures II LLC

**Example American Count XII Systems and Services
U.S. Patent No. 7,721,282 (“the ’282 Patent”)**

The Accused Systems and Services include without limitation American systems and services that utilize Docker; all past, current, and future systems and services that operate in the same or substantially similar manner as the specifically identified systems and services; and all past, current, and future American systems and services that have the same or substantially similar features as the specifically identified systems and services (“Example American Count XII Systems and Services” or “American Systems and Services”).¹

On information and belief, the American Systems and Services use Docker in public and/or private cloud(s). For example, American posts, or has posted, job opportunities that require familiarity with Docker containerization concepts.

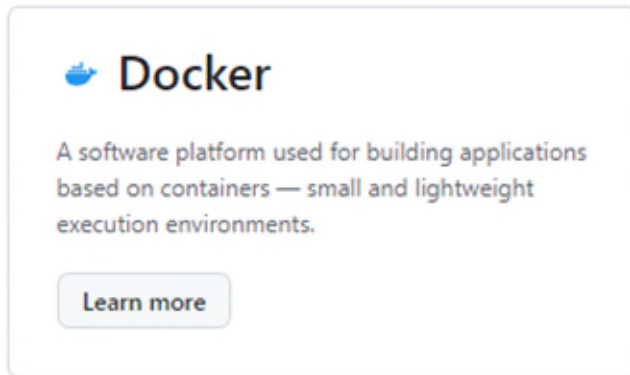
- Example of job posting for an Engineer/Sr Engineer in IT Situational Awareness at American Airlines which mentions Docker as a necessary skill for the position. https://jobs.aa.com/job/EngineerSr-Engineer%2C-IT-Situational-Awareness/75837-en_US. (Last accessed on 10/31/2024).
- Example of job posting for an Associate Developer in IT Applications at American Airlines which mentions Docker as a necessary skill for the position. https://jobs.aa.com/job/Associate-Developer%2C-IT-Applications/75816-en_US. (Last accessed on 10/31/2024).
- Example of Sr. Cloud Infra DevSecOps Engineer/Architect position at American Airlines which mentions use of Docker. <https://www.linkedin.com/in/rupa-m-b90836309/>. (Last accessed on 9/19/24).
- Example of Kubernetes Engineer position at American Airlines which mentions use of Docker. <https://www.linkedin.com/in/sridhar-pulluri-199b56250/>. (Last accessed on 9/19/24)
- Example of Software Engineer position at American Airlines which mentions use of Docker. <https://www.linkedin.com/in/pthotakura9/>. (Last accessed on 9/19/24)

¹ Plaintiffs do not accuse the public clouds of Defendant, to the extent those services are provided by a cloud provider with a license to Plaintiffs’ patents that covers Defendant’s activities. As a specific example, Plaintiffs do not accuse Amazon managed services, *i.e.*, Amazon Elastic Kubernetes Service (Amazon EKS) and Amazon Elastic Container Service (Amazon ECS). Plaintiffs also does not accuse IBM managed services, *i.e.*, Red Hat Open Shift. Plaintiffs do not accuse the public clouds of Defendants if those services are provided by a cloud provider with a license to Plaintiffs’ patents that covers Defendants’ activities. Plaintiffs will produce relevant license agreements in this litigation. Plaintiffs accuse Defendant private clouds that implement Docker and non-licensed public clouds that Defendant uses to support Docker for its systems and services. Plaintiffs will provide relevant license agreements for cloud providers in discovery, to the extent any such license agreements have not already been produced. To the extent any of these licenses are relevant to Defendant’s activities, Plaintiffs will meet and confer with Defendant about the impact of such license(s).

- Example of Senior Developer, IT Applications position at American Airlines which mentions use of Docker. <https://www.linkedin.com/in/cj-cohorst-61a614173/>. (Last accessed on 9/19/24)
- Example of Developer position at American Airlines which mentions use of Docker. <https://in.linkedin.com/in/prudhvikumar-rayapati>.

As another example, American has announced cloud migration of legacy technology and efforts to modernize its mainframes and servers. Source: <https://dxc.com/sg/en/insights/customer-stories/american-airlines-cloud-data-automation>. American continues to use private cloud for at least certain applications. Source: <https://www.techtarget.com/searchdatamanagement/feature/American-Airlines-lowers-data-management-costs-with-Intel>. (“American Airlines’ initial target for cost optimization was Azure Data Lake, according to Vijay Premkumar, senior manager of public and *private cloud* at the airline.”) (emphasis added).

On information and belief, other information confirmed American uses Docker technology.



Source: <https://github.com/orgs/americanair/packages>.



Top Airlines, Airports & Air Services Companies Using Docker

37,841 companies using this technology

By [Docker](#)

Docker is a software container platform. Developers use Docker to eliminate “works on my machine” problems when collaborating on code with co-workers. Operators use Docker to run and manage apps side-by-side in isolated containers to get better compute density. Enterprises use Docker to build agile software delivery pipelines. [Read less](#)



American Airlines

Technologies used by the company: 1,293

Source: <https://www.zoominfo.com/tech/23717/docker-tech-from-transportation-airline-industry-in-us-by-revenue>.

When I came to American Airlines, I tried to contribute to several InnerSource projects in our corporate VCS. One of the things I observed is that local development leaned on local installations of the application framework extensively. In the past, I've been victim of "worked on my machine" in similar setups and wanted to get a better understanding of how pervasive containers were being used. I wanted to present options on how to use containers to help remove local dependency hell. There was plenty of opportunity to leverage this approach for local development 🙏

Using containers for a local development environment can help remove impediments in situations such as:

- My stack has several dependencies that are hard to emulate:
 - Databases, and associated volumes for (short-lived) storage
 - Caches
 - Connectivity to the above, with declarative service names
- I have a bunch of application dependencies (`requirements.txt`, `packages.json`, `Gemfile`)
- There are many moving parts to reproduce a production-like environment
- My team uses different operating systems, or versions of operating systems

Windows and macOS

- Install Docker – `stable` or `edge` is fine. For the purposes of this write-up, we're using basic features.

Source: <https://tech.aa.com/2020-10-13-containers-local-dev/>.

Karl Haworth, is a Principal Staff Engineer on American Airlines Developer Experience products. His team is leveraging Chainguard Images to harden their software and strengthen the security of their software supply chain. Karl recently created an alternative, secure image for the Backstage open-source framework using Chainguard's wolfi-base image. In this guest post, Karl explores the decision to use wolfi-base and the benefits he has seen in reducing vulnerabilities and shrinking the overall Backstage attack surface.

American Airlines is committed to enhancing the developer experience by implementing a frictionless self-service platform to create delightful developer experiences. By doing so, the developers can deliver value *sooner* to our customers. In order to achieve the stated goal, we adopted Spotify's [Backstage](#) open-source framework for accelerating the development of our internal developer portal Runway. This marks my third endeavor at establishing a developer portal which has been successful due to a heavy focus on InnerSource practices. Backstage has proven instrumental in streamlining the development process, thanks to its community-driven foundation as a solid base to build upon.

While Backstage prioritizes security, concerns arise when utilizing the base image, `node:18-bookworm-slim`, as it contains 74 vulnerabilities ranging in severity. This has prompted us to assess the security implications when using the docker build command and `Dockerfile` within the Backstage framework, as the default added an additional 330 vulnerabilities. I attempted using updated node and Debian images, but they also yielded similar results, prompting me to seek out different solutions.

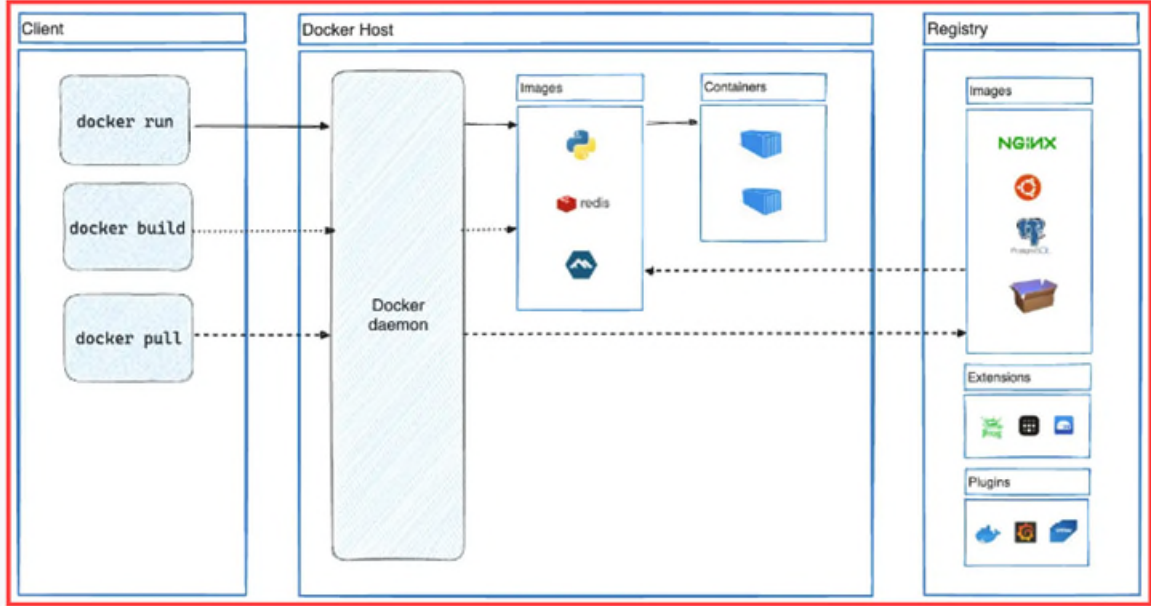
Source: <https://www.chainguard.dev/unchained/reducing-vulnerabilities-in-backstage-with-chainguards-wolfi>. See also <https://karlhaworth.com/>.²

² Unless otherwise noted, all sources cited in this document were publicly accessible as of the filing date of the Complaint.

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
1. A system for distributing an application environment comprising:	<p>To the extent this preamble is limiting, on information and belief, the American Count XII Systems and Services are a “system for distributing an application environment.”</p> <p>Docker is an open-source platform that enables the development and distribution of applications and facilitates running applications in an isolated environment called containers. A multi-server environment capable of deploying and running Docker containers is considered a system.</p> <div><h3>Docker overview</h3><p>Docker is an open platform for developing, shipping, and running applications. Docker enables you to separate your applications from your infrastructure so you can deliver software quickly. With Docker, you can manage your infrastructure in the same ways you manage your applications. By taking advantage of Docker’s methodologies for shipping, testing, and deploying code, you can significantly reduce the delay between writing code and running it in production.</p></div> <p>Source: https://docs.docker.com/guides/docker-overview/.³ (Last accessed on May 15, 2025).</p>

³ Annotations added unless otherwise noted.

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	<div><h2>The Docker platform</h2><p>Docker provides the ability to package and run an application in a loosely isolated environment called a container. The isolation and security lets you run many containers simultaneously on a given host.</p><p>Containers are lightweight and contain everything needed to run the application, so you don't need to rely on what's installed on the host. You can share containers while you work, and be sure that everyone you share with gets the same container that works in the same way.</p><p>Docker provides tooling and a platform to manage the lifecycle of your containers:</p><ul style="list-style-type: none">• Develop your application and its supporting components using containers.• The container becomes the unit for distributing and testing your application.• When you're ready, deploy your application into your production environment, as a container or an orchestrated service. This works the same whether your production environment is a local data center, a cloud provider, or a hybrid of the two.<p>Source: https://docs.docker.com/guides/docker-overview/. (Last accessed on May 15, 2025).</p><p>For example, a user can interact with Docker on the command line to run, build, pull, and/or configure containers, images, and/or volumes.</p></div>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	 <p>The diagram illustrates the Docker architecture. On the left, the 'Client' box contains three components: 'docker run', 'docker build', and 'docker pull'. In the center, the 'Docker Host' box contains a large 'Docker daemon' box. To the right of the daemon are two boxes: 'Images' (containing icons for Python, Redis, and Docker) and 'Containers' (containing two Docker container icons). On the far right, the 'Registry' box contains three sections: 'Images' (with icons for NGINX, Redis, and Docker), 'Extensions' (with icons for Jenkins, Kubernetes, and Docker), and 'Plugins' (with icons for Docker, Kubernetes, and Docker). Arrows indicate the flow of data: 'docker run' points to the 'Docker daemon'; 'docker build' points to the 'Docker daemon'; 'docker pull' points to the 'Docker daemon'; the 'Docker daemon' points to the 'Images' box in the 'Docker Host'; the 'Images' box in the 'Docker Host' points to the 'Containers' box; the 'Docker daemon' points to the 'Images' box in the 'Registry'; and the 'Images' box in the 'Registry' points to the 'Images' box in the 'Docker Host'.</p> <p>Source: https://docs.docker.com/guides/docker-overview/. (Last accessed on May 15, 2025).</p>
1[a] a compute node comprising a computer system;	<p>On information and belief, the American Count XII Systems and Services include “a compute node comprising a computer system.”</p> <p>Docker requires a host environment or a server to host containers in isolation from each other. Containers (e.g., a compute node) are running instances of an image, having executable packages of software, including code, runtime, system tools, libraries, and settings (e.g., comprising a computer system).</p>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	<p>A container is a standard unit of software that packages up code and all its dependencies so the application runs quickly and reliably from one computing environment to another. A Docker container image is a lightweight, standalone, executable package of software that includes everything needed to run an application: code, runtime, system tools, system libraries and settings.</p> <p>Source: https://www.docker.com/resources/what-container/. (Last accessed on May 15, 2025).</p> <div data-bbox="980 789 1495 1224" data-label="Diagram"> <p style="text-align: center;">Containerized Applications</p> <pre> graph TD subgraph CA [Containerized Applications] direction TB AppA[App A] AppB[App B] AppC[App C] AppD[App D] AppE[App E] AppF[App F] end CA --- Docker[Docker] Docker --- HOS[Host Operating System] HOS --- Infrastructure[Infrastructure] </pre> </div> <p>Source: https://www.docker.com/resources/what-container/ (Last accessed on May 15, 2025).</p>

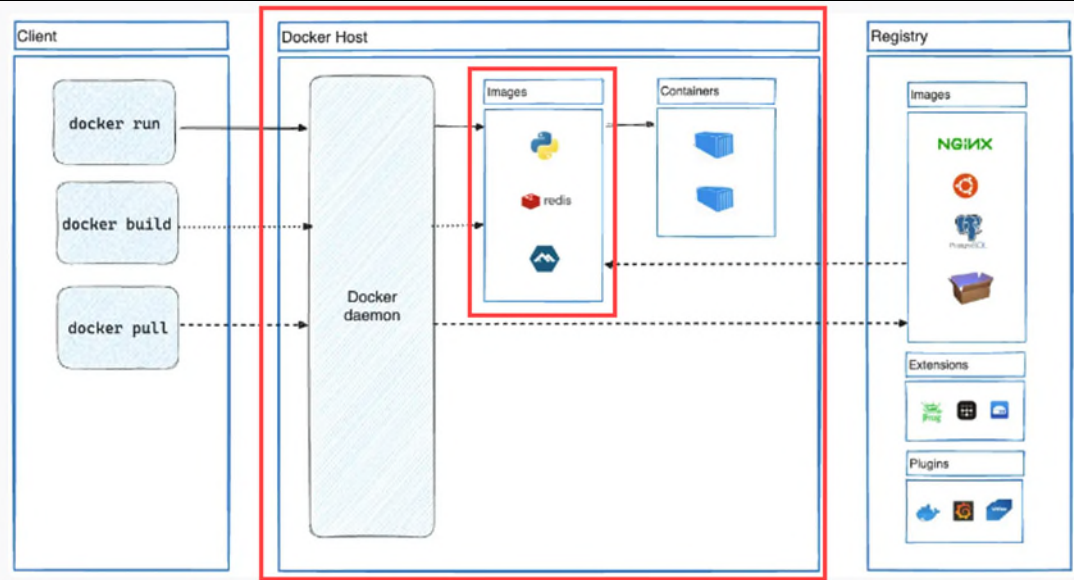
U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	<p>The Docker platform</p> <p>Docker provides the ability to package and run an application in a loosely isolated environment called a container. The isolation and security lets you run many containers simultaneously on a given host. Containers are lightweight and contain everything needed to run the application, so you don't need to rely on what's installed on the host. You can share containers while you work, and be sure that everyone you share with gets the same container that works in the same way.</p> <p>Source: https://docs.docker.com/get-started/docker-overview/. (Last accessed on May 15, 2025).</p> <p>By default, a container is relatively well isolated from other containers and its host machine. You can control how isolated a container's network, storage, or other underlying subsystems are from other containers or from the host machine.</p> <p>Source: https://docs.docker.com/get-started/docker-overview/. (Last accessed on May 15, 2025).</p> <p>For example, containers are running instances of images. Docker images include the libraries, dependencies, and other environment elements for an application to run in. The storage driver controls how the images and container instances are resident on the host.</p> <p>Images and containers</p> <p>Fundamentally, a container is nothing but a running process, with some added encapsulation features applied to it in order to keep it isolated from the host and from other containers. One of the most important aspects of container isolation is that each container interacts with its own private filesystem; this filesystem is provided by a Docker image. An image includes everything needed to run an application - the code or binary, runtimes, dependencies, and any other filesystem objects required.</p> <p>Source: https://docker-docs.uclv.cu/get-started/. (Last accessed on May 15, 2025).</p>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	<p>Docker supports several storage drivers, using a pluggable architecture. The storage driver controls how images and containers are stored and managed on your Docker host. After you have read the storage driver overview, the next step is to choose the best storage driver for your workloads. Use the storage driver with the best overall performance and stability in the most usual scenarios.</p> <p>Source: https://docs.docker.com/storage/storagedriver/select-storage-driver/. (Last accessed on May 15, 2025).</p>
1[b] a first storage unit for storing blocks of a root image of the compute node, wherein the first storage unit comprises a first non-volatile memory, wherein the root image comprises a computer program, wherein the blocks comprise sections of data, and wherein a file of the root image comprises at least one block;	<p>On information and belief, the American Count XII Systems and Services include “a first storage unit for storing blocks of a root image of the compute node, wherein the first storage unit comprises a first non-volatile memory, wherein the root image comprises a computer program, wherein the blocks comprise sections of data, and wherein a file of the root image comprises at least one block.”</p> <p>Docker containers each have their own private filesystem provided by a Docker image. Docker provides storage drivers that control how the images and containers are stored and managed on a Docker host.</p> <p>Docker supports several storage drivers, using a pluggable architecture. The storage driver controls how images and containers are stored and managed on your Docker host. After you have read the storage driver overview, the next step is to choose the best storage driver for your workloads. Use the storage driver with the best overall performance and stability in the most usual scenarios.</p> <p>Source: https://docs.docker.com/storage/storagedriver/select-storage-driver/. (Last accessed on May 15, 2025).</p>

U.S. Patent No. 7,721,282 (Claim 1)

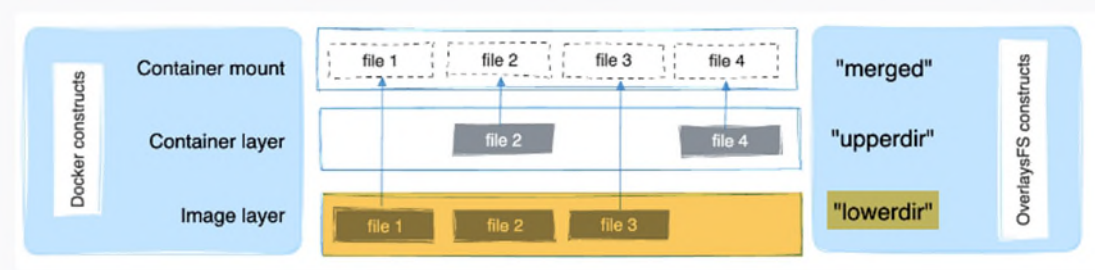
Claim

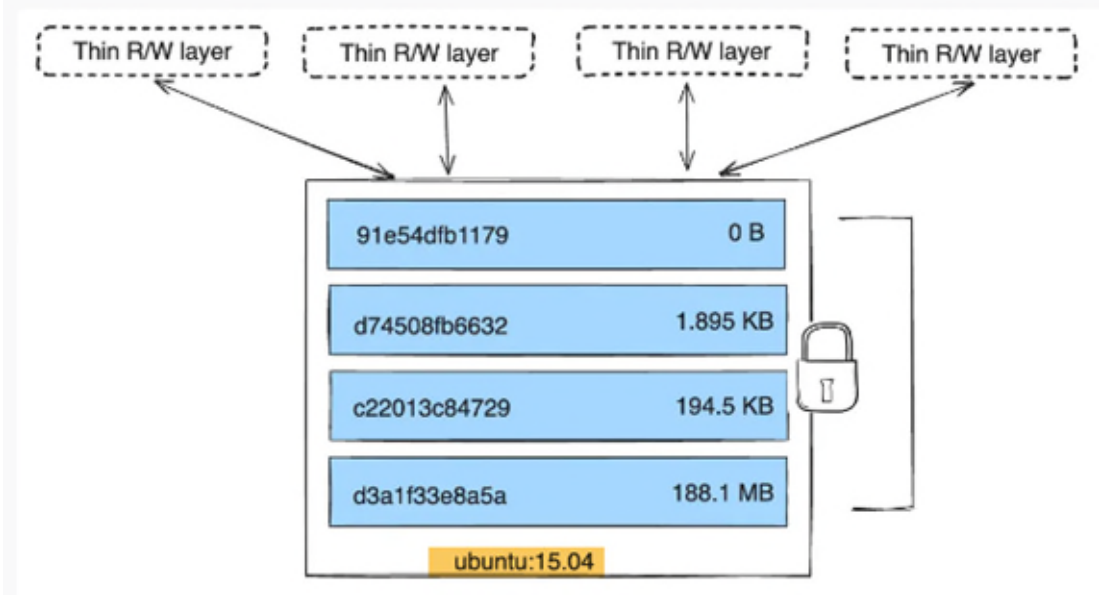
Example American Count XII Systems and Services

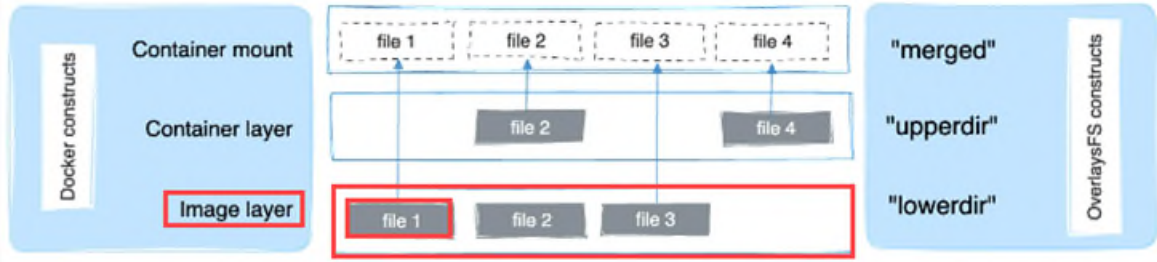


Source: <https://docs.docker.com/guides/docker-overview/>. (Last accessed on May 15, 2025).

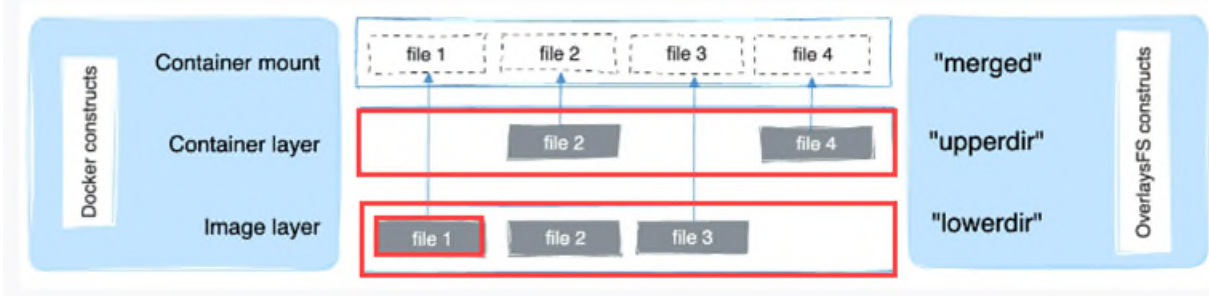
For example, Docker stores images and containers in memory on the host system. Particularly, Docker, through its OverlayFS (Overlay File System), presents all the directories as a single consolidated directory. The lower directory is called 'lowerdir' and the upper directory is called 'upperdir'. The 'lowerdir' is the layer that stores blocks of the base or root image. The base or root image includes the application code, dependencies, and other necessary elements for execution or runtime. Each layer, or the files therein, occupies a portion of the 'lowerdir'.

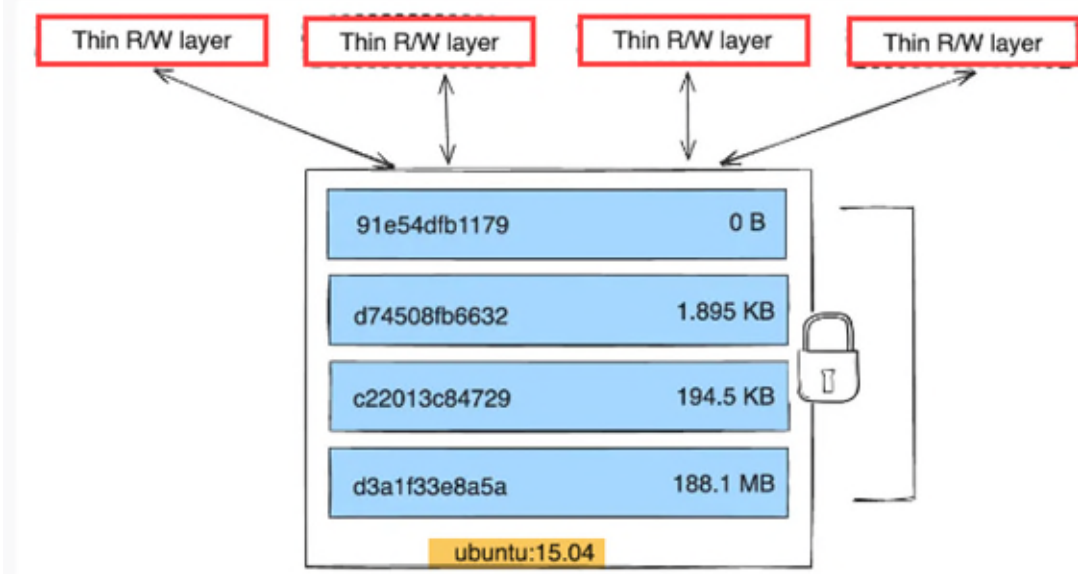
Claim	U.S. Patent No. 7,721,282 (Claim 1)
	Example American Count XII Systems and Services
	<p data-bbox="787 324 1245 354">Image and container layers on-disk</p> <p data-bbox="787 381 1682 440">After downloading a five-layer image using <code>docker pull ubuntu</code>, you can see six directories under <code>/var/lib/docker/overlay2</code>.</p> <div data-bbox="787 479 1745 651"> <p>⊗ Warning</p> <p>Don't directly manipulate any files or directories within <code>/var/lib/docker/</code>. These files and directories are managed by Docker.</p> </div> <pre data-bbox="787 683 1745 1015"> \$ ls -l /var/lib/docker/overlay2 total 24 drwx----- 5 root root 4096 Jun 20 07:36 223c2864175491657d238e2664251df13b63adb8d050924f drwx----- 3 root root 4096 Jun 20 07:36 3a36935c9df35472229c57f4a27105a136f5e4dbef0f8796 drwx----- 5 root root 4096 Jun 20 07:36 4e9fa83caff3e8f4cc83693fa407a4a9fac9573deaf48156 drwx----- 5 root root 4096 Jun 20 07:36 e8876a226237217ec61c4baf238a32992291d059fdac95ec drwx----- 5 root root 4096 Jun 20 07:36 eca1e4e1694283e001f200a667bb3cb40853cf2d1b12c29f drwx----- 2 root root 4096 Jun 20 07:36 1 </pre> <p data-bbox="611 1050 1875 1117">Source: https://docs.docker.com/storage/storagedriver/overlayfs-driver/. (Last accessed on May 15, 2025).</p>  <p>The diagram illustrates the Docker storage architecture. On the left, a box labeled 'Docker constructs' contains three components: 'Container mount', 'Container layer', and 'Image layer'. In the center, a visual representation shows a 'merged' directory at the top containing 'file 1', 'file 2', 'file 3', and 'file 4'. Below this is the 'upperdir' (containing 'file 2' and 'file 4') and at the bottom is the 'lowerdir' (containing 'file 1', 'file 2', and 'file 3'). On the right, a box labeled 'OverlayFS constructs' contains 'merged', 'upperdir', and 'lowerdir'. Arrows indicate the flow of data and layering between these components.</p>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	<p>Source: https://docs.docker.com/storage/storagedriver/overlayfs-driver/. (Last accessed on May 15, 2025).</p>  <p>Source: https://docs.docker.com/storage/storagedriver/. (Last accessed on May 15, 2025).</p> <p>As shown in the evidence below, each layer can include multiple files. For example, an image layer can include three files, where each of these files includes at least one block of data. A user can see a consolidated view via the merged directory, which is a combined view of the ‘lowerdir’ and ‘upperdir’ via overlay2, the storage driver in OverlayFS.</p>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	<p>The following diagram shows how a Docker image and a Docker container are layered. The image layer is the <code>lowerdir</code> and the container layer is the <code>upperdir</code>. If the image has multiple layers, multiple <code>lowerdir</code> directories are used. The unified view is exposed through a directory called <code>merged</code> which is effectively the containers mount point.</p>  <p>Source: https://docs.docker.com/storage/storagedriver/overlayfs-driver/. (Last accessed on May 15, 2025).</p> <p>Image and container layers on-disk</p> <p>After downloading a five-layer image using <code>docker pull ubuntu</code>, you can see six directories under <code>/var/lib/docker/overlay2</code>.</p> <p>Source: https://docs.docker.com/storage/storagedriver/overlayfs-driver/. (Last accessed on May 15, 2025).</p>
<p>1[c] a second storage unit for storing a leaf image, the leaf image comprising new data blocks and changes to the blocks of the root image,</p>	<p>On information and belief, the American Count XII Systems and Services include “a first storage unit for storing blocks of a root image of the compute node, wherein the first storage unit comprises a first non-volatile memory, wherein the root image comprises a computer program, wherein the blocks comprise sections of data, and wherein a file of the root image comprises at least one block.”</p> <p>Docker includes a top writable layer, where all writes to a container (e.g., a write to add new data or</p>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
wherein the second storage unit comprises a second non-volatile memory; and	<p>modify existing data) are stored in the writable layer. The writable layer contains only the modified data per the changes made by the respective container instance. The writable layer is stored in memory.</p> <div data-bbox="718 418 1150 469" data-label="Section-Header"> <h3>Container and layers</h3> </div> <div data-bbox="718 496 1818 609" data-label="Text"> <p>The major difference between a container and an image is the top writable layer. All writes to the container that add new or modify existing data are stored in this writable layer. When the container is deleted, the writable layer is also deleted. The underlying image remains unchanged.</p> </div> <p>Source: https://docs.docker.com/storage/storagedriver/. (Last accessed on May 15, 2025).</p> <div data-bbox="672 706 1860 909" data-label="Text"> <p>Each layer is only a set of differences from the layer before it. Note that both <i>adding</i>, and <i>removing</i> files will result in a new layer. In the example above, the <code>\$HOME/.cache</code> directory is removed, but will still be available in the previous layer and add up to the image's total size. Refer to the Best practices for writing Dockerfiles and use multi-stage builds sections to learn how to optimize your Dockerfiles for efficient images.</p> </div> <div data-bbox="672 953 1864 1114" data-label="Text"> <p>The layers are stacked on top of each other. When you create a new container, you add a new writable layer on top of the underlying layers. This layer is often called the "container layer". All changes made to the running container, such as writing new files, modifying existing files, and deleting files, are written to this thin writable container layer. The diagram below shows a container based on an <code>ubuntu:15.04</code> image.</p> </div> <p>Source: https://docs.docker.com/storage/storagedriver/. (Last accessed on May 15, 2025).</p> <p>For example, the changes, edits, or modifications made to a container will be stored in the 'upperdir' of that container. The 'upperdir' includes only the changed, edited, or modified file(s) by the container.</p>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	<p>The following diagram shows how a Docker image and a Docker container are layered. The image layer is the <code>lowerdir</code> and the container layer is the <code>upperdir</code>. If the image has multiple layers, multiple <code>lowerdir</code> directories are used. The unified view is exposed through a directory called <code>merged</code> which is effectively the containers mount point.</p>  <p>The diagram illustrates the layering of a Docker image and container. On the left, a blue box labeled 'Docker constructs' contains 'Container mount', 'Container layer', and 'Image layer'. On the right, a blue box labeled 'OverlaysFS constructs' contains '"merged"', '"upperdir"', and '"lowerdir"'. The central part shows a hierarchy: a top row of four boxes labeled 'file 1', 'file 2', 'file 3', and 'file 4' (representing the merged view). Below this is a red-outlined box labeled '"upperdir"' containing 'file 2' and 'file 4'. Below that is another red-outlined box labeled '"lowerdir"' containing 'file 1', 'file 2', and 'file 3'. Arrows point from the 'merged' row down to the 'upperdir' box, and from the 'upperdir' box down to the 'lowerdir' box, indicating the layering and mounting process.</p> <p>Source: https://docs.docker.com/storage/storagedriver/overlayfs-driver/. (Last accessed on May 15, 2025).</p>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	 <p>The diagram illustrates a storage architecture for container images. At the top, four red-outlined boxes labeled "Thin R/W layer" are arranged horizontally. Below them is a large container image box. The container image box contains four blue-outlined boxes, each representing a layer with a hash and a size: "91e54dfb1179" (0 B), "d74508fb6632" (1.895 KB), "c22013c84729" (194.5 KB), and "d3a1f33e8a5a" (188.1 MB). A yellow box at the bottom of the container image box is labeled "ubuntu:15.04". A padlock icon is positioned to the right of the container image box, indicating it is locked or immutable. Arrows show the relationship between the thin R/W layers and the container image layers: the first thin R/W layer points to the first container layer, the second thin R/W layer points to the second container layer, the third thin R/W layer points to the third container layer, and the fourth thin R/W layer points to the fourth container layer. Additionally, a double-headed arrow connects the second and third thin R/W layers, and another double-headed arrow connects the third and fourth thin R/W layers.</p> <p>Source: https://docs.docker.com/storage/storagedriver/. (Last accessed on May 15, 2025).</p> <p>For example, below describes how overlay2 functions by comparing and calculating the differences or changes between the parent and its corresponding layer, if it was modified.</p>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	<pre> // DiffSize calculates the changes between the specified id // and its parent and returns the size in bytes of the changes // relative to its base filesystem directory. func (d *Driver) DiffSize(id, parent string) (int64, error) { if useNaiveDiff(d.home) !d.isParent(id, parent) { return d.naiveDiff.DiffSize(id, parent) } return directory.Size(context.TODO(), d.getDiffPath(id)) } // Diff produces an archive of the changes between the specified // layer and its parent layer which may be "". func (d *Driver) Diff(id, parent string) (io.ReadCloser, error) { if useNaiveDiff(d.home) !d.isParent(id, parent) { return d.naiveDiff.Diff(id, parent) } } // Changes produces a list of changes between the specified layer and its // parent layer. If parent is "", then all changes will be ADD changes. func (d *Driver) Changes(id, parent string) ([]archive.Change, error) { return d.naiveDiff.Changes(id, parent) } </pre> <p>Source: https://github.com/moby/moby/blob/master/daemon/graphdriver/overlay2/overlay.go. (Last Accessed on May 15, 2025).</p>

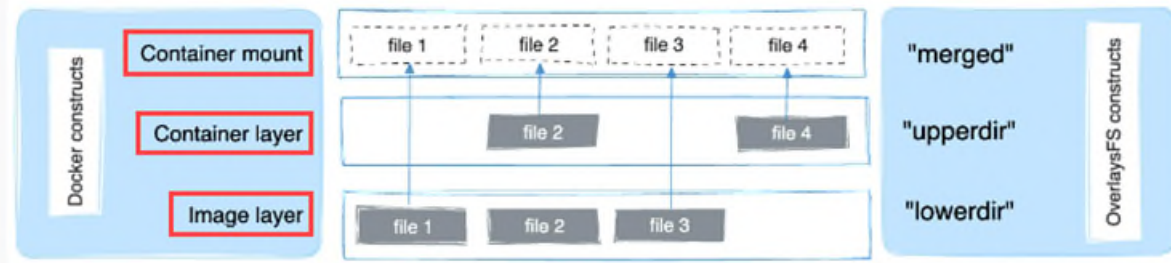
U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
<p>1[d] a union block device for interfacing between the compute node and the first and second storage units to distribute the application environment to the compute node, wherein the union block device comprises a driver, wherein the union block device creates the application environment by merging the blocks of the root image stored on the first storage unit with the blocks of the leaf image stored on the second storage unit; the union block device comprises a low-level driver for interfacing between the first and second storage units and the file system of the compute node; and the union block device, upon receiving a write request from the compute node for a sector X, creates an appropriate persistent mapping for sector X.</p>	<p>On information and belief, the American Count XII Systems and Services include “a union block device for interfacing between the compute node and the first and second storage units to distribute the application environment to the compute node, wherein the union block device comprises a driver, wherein the union block device creates the application environment by merging the blocks of the root image stored on the first storage unit with the blocks of the leaf image stored on the second storage unit; the union block device comprises a low-level driver for interfacing between the first and second storage units and the file system of the compute node; and the union block device, upon receiving a write request from the compute node for a sector X, creates an appropriate persistent mapping for sector X.”</p> <p>Docker enables building, running, and sharing applications using containers. Docker provides a storage driver – overlay2, for managing and storing images for use. The overlay2 storage driver provides a mechanism for interfacing between the container and storage units.</p> <div data-bbox="659 743 1860 1185"> <h3>How the overlay2 driver works</h3> <p>OverlayFS layers two directories on a single Linux host and presents them as a single directory. These directories are called layers, and the unification process is referred to as a union mount. OverlayFS refers to the lower directory as <code>lowerdir</code> and the upper directory as <code>upperdir</code>. The unified view is exposed through its own directory called <code>merged</code>.</p> <p>The <code>overlay2</code> driver natively supports up to 128 lower OverlayFS layers. This capability provides better performance for layer-related Docker commands such as <code>docker build</code> and <code>docker commit</code>, and consumes fewer inodes on the backing filesystem.</p> </div> <p>Source: https://docs.docker.com/storage/storagedriver/overlayfs-driver/. (Last accessed on May 15, 2025).</p>

U.S. Patent No. 7,721,282 (Claim 1)

Claim

Example American Count XII Systems and Services

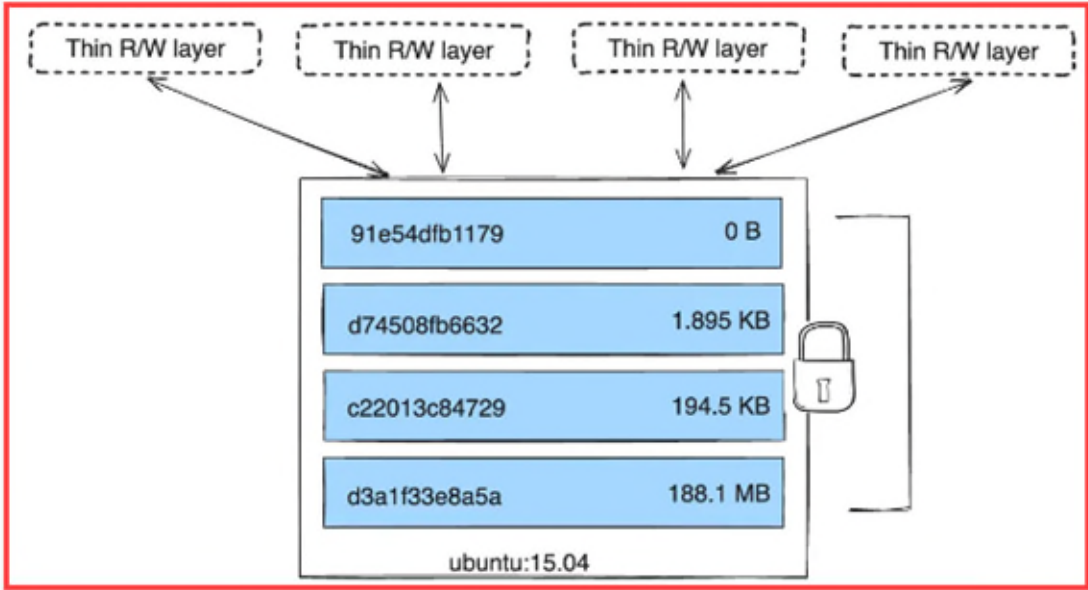
The following diagram shows how a Docker image and a Docker container are layered. The image layer is the `lowerdir` and the container layer is the `upperdir`. If the image has multiple layers, multiple `lowerdir` directories are used. The unified view is exposed through a directory called `merged` which is effectively the containers mount point.



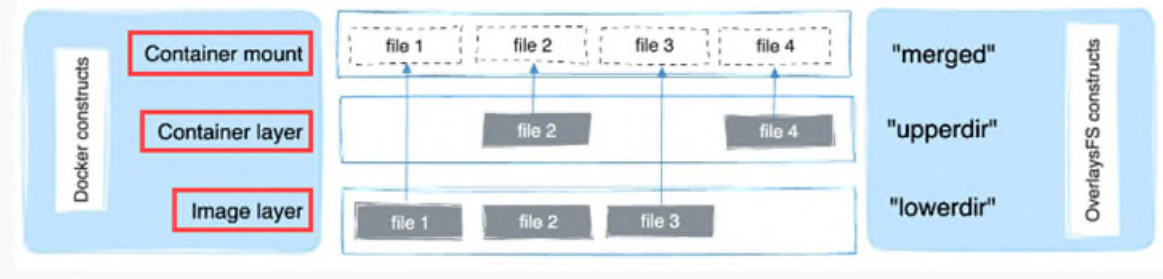
Source: <https://docs.docker.com/storage/storagedriver/overlayfs-driver/>. (Last accessed on May 15, 2025).

To create a container, the `overlay2` driver combines the directory representing the image's top layer plus a new directory for the container. The image's layers are the `lowerdirs` in the overlay and are read-only. The new directory for the container is the `upperdir` and is writable.

Source: <https://docs.docker.com/storage/storagedriver/overlayfs-driver/>. (Last accessed on May 15, 2025).

U.S. Patent No. 7,721,282 (Claim 1)	
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	 <p>The diagram illustrates a storage architecture for containers. At the top, four dashed boxes labeled 'Thin R/W layer' are shown. Below them is a stack of four solid blue boxes representing image layers. The layers are labeled with their IDs and sizes: '91e54dfb1179' (0 B), 'd74508fb6632' (1.895 KB), 'c22013c84729' (194.5 KB), and 'd3a1f33e8a5a' (188.1 MB). The bottom layer is labeled 'ubuntu:15.04'. A padlock icon is positioned to the right of the stack, indicating that the base image is read-only. Arrows show the relationship between the thin R/W layers and the underlying image stack.</p> <p>Source: https://docs.docker.com/storage/storagedriver/. (Last accessed on May 15, 2025).</p> <p>Images and containers</p> <p>Fundamentally, a container is nothing but a running process, with some added encapsulation features applied to it in order to keep it isolated from the host and from other containers. One of the most important aspects of container isolation is that each container interacts with its own private filesystem; this filesystem is provided by a Docker image. An image includes everything needed to run an application - the code or binary, runtimes, dependencies, and any other filesystem objects required.</p> <p>Source: https://docker-docs.uclv.cu/get-started/. (Last accessed on May 15, 2025).</p> <p>Docker includes an OverlayFS union filesystem that includes a storage driver, overlay2. OverlayFS includes the image layer and the container layer, which are presented as a single directory in a process called a union mount. In a container filesystem, the overlay2 storage driver combines directories representing the image's read-only layer and writable layers.</p>

U.S. Patent No. 7,721,282 (Claim 1)	
Claim	Example American Count XII Systems and Services
	<div><h2>Use the OverlayFS storage driver</h2><p>OverlayFS is a union filesystem.</p><p>This page refers to the Linux kernel driver as <code>OverlayFS</code> and to the Docker storage driver as <code>overlay2</code>.</p><h3>How the <code>overlay2</code> driver works</h3><p>OverlayFS layers two directories on a single Linux host and presents them as a single directory. These directories are called layers, and the unification process is referred to as a union mount. OverlayFS refers to the lower directory as <code>lowerdir</code> and the upper directory as <code>upperdir</code>. The unified view is exposed through its own directory called <code>merged</code>.</p><p>The <code>overlay2</code> driver natively supports up to 128 lower OverlayFS layers. This capability provides better performance for layer-related Docker commands such as <code>docker build</code> and <code>docker commit</code>, and consumes fewer inodes on the backing filesystem.</p><p>Source: https://docs.docker.com/storage/storagedriver/overlayfs-driver/. (Last accessed on May 15, 2025).</p><p>For example, Docker refers to the base image layers as ‘lowerdir’ and the container layer as ‘upperdir,’ and the unified view is referred to as merged.</p></div>

U.S. Patent No. 7,721,282 (Claim 1)	
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	<p>The following diagram shows how a Docker image and a Docker container are layered. The image layer is the <code>lowerdir</code> and the container layer is the <code>upperdir</code>. If the image has multiple layers, multiple <code>lowerdir</code> directories are used. The unified view is exposed through a directory called <code>merged</code> which is effectively the containers mount point.</p>  <p>Source: https://docs.docker.com/storage/storagedriver/overlayfs-driver/. (Last accessed on May 15, 2025).</p> <p>Furthermore, all writes are made in the top writable layer (container layer / 'upperdir'). Based on information and belief, it is assumed that writes are made in a specific portion of the writable layer, particularly in the case of modifications made to the existing data stored in an already known portion of the writable layer.</p> <h3>Container and layers</h3> <p>The major difference between a container and an image is the top writable layer. All writes to the container that add new or modify existing data are stored in this writable layer. When the container is deleted, the writable layer is also deleted. The underlying image remains unchanged.</p> <p>Source: https://docs.docker.com/storage/storagedriver/. (Last accessed on May 15, 2025).</p>

U.S. Patent No. 7,721,282 (Claim 1)	
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	<p>The second-lowest layer, and each higher layer, contain a file called <code>lower</code>, which denotes its parent, and a directory called <code>diff</code> which contains its contents. It also contains a <code>merged</code> directory, which contains the unified contents of its parent layer and itself, and a <code>work</code> directory which is used internally by OverlayFS.</p> <p>Source: https://docs.docker.com/engine/storage/drivers/overlayfs-driver/. (Last accessed on May 15, 2025).</p> <p>The first time a container writes to an existing file, that file does not exist in the container (<code>upperdir</code>). The <code>overlay2</code> driver performs a <code>copy_up</code> operation to copy the file from the image (<code>lowerdir</code>) to the container (<code>upperdir</code>). The container then writes the changes to the new copy of the file in the container layer.</p> <p>However, OverlayFS works at the file level rather than the block level. This means that all OverlayFS <code>copy_up</code> operations copy the entire file, even if the file is large and only a small part of it's being modified. This can have a noticeable impact on container write performance. However, two things are worth noting:</p> <p>Source: https://docs.docker.com/engine/storage/drivers/overlayfs-driver/. (Last accessed on May 15, 2025).</p> <p>For example, the 'lowerdir' directory can be seen by the <code>getLowerDirs</code> function to return all the files associated with the parent or base image.</p>

U.S. Patent No. 7,721,282 (Claim 1)	
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	<pre> 468 func (d *Driver) getLowerDirs(id string) ([]string, error) { 469 var lowersArray []string 470 lowers, err := os.ReadFile(path.Join(d.dir(id), lowerFile)) 471 if err == nil { 472 for _, s := range strings.Split(string(lowers), ":") { 473 lp, err := os.Readlink(path.Join(d.home, s)) 474 if err != nil { 475 return nil, err 476 } 477 lowersArray = append(lowersArray, path.Clean(path.Join(d.home, linkDir, lp))) 478 } 479 } else if !os.IsNotExist(err) { 480 return nil, err 481 } 482 return lowersArray, nil </pre> <p>Source: https://github.com/moby/moby/blob/master/daemon/graphdriver/overlay2/overlay.go. (Last accessed on May 15, 2025).</p> <p>Furthermore, overlay2 first looks at if there have been any modifications at the writable layer. It will then merge the lower and upper directories and return that as the mount path of the container. For example, within a container, by listing out the files.</p> <pre> 508 // Get creates and mounts the required file system for the given id and returns the mount path. 509 func (d *Driver) Get(id, mountLabel string) (_ string, retErr error) { </pre>

U.S. Patent No. 7,721,282 (Claim 1)	
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	<pre> 527 mergedDir := path.Join(dir, mergedDirName) 528 if count := d.ctr.Increment(mergedDir); count > 1 { 529 return mergedDir, nil 530 } 531 defer func() { 532 if retErr != nil { 533 if c := d.ctr.Decrement(mergedDir); c <= 0 { 534 if mntErr := unix.Unmount(mergedDir, 0); mntErr != nil { 535 logger.Errorf("error unmounting %v: %v", mergedDir, mntErr) 536 } 537 // Cleanup the created merged directory; see the comment in Put's rmdir 538 if rmErr := unix.Rmdir(mergedDir); rmErr != nil && !os.IsNotExist(rmErr) { 539 logger.Debugf("Failed to remove %s: %v: %v", id, rmErr, err) 540 } 541 } 542 } 543 }() 565 mountData := label.FormatMountLabel(opts, mountLabel) 566 mount := unix.Mount 567 mountTarget := mergedDir </pre> <p>Source: https://github.com/moby/moby/blob/master/daemon/graphdriver/overlay2/overlay.go. (Last accessed on May 15, 2025).</p>